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LEAD POISONING IN WATERFOWL.

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INTRODUCTION.

Lead poisoning in various species of wild ducks and other waterfowl has recently attracted attention among persons interested in game birds in the United States. Though for a number of years this disease has been reported in periodicals devoted to sport and from other sources, it is little recognized and understood, and few sportsmen have any knowledge of it. Already it is causing the loss of a considerable number of waterfowl each year, and there is no doubt that as time goes on it will assume greater importance. Lead poisoning in waterfowl has its origin in the large quantity of expended shot that from year to year is deposited in the mud about shooting points and blinds in marshes, shallow bays, and lakes. Birds find and swallow these leaden pellets while searching for food, and many are seriously affected by the poison thus taken. Present knowledge indicates that the mallard, canvas-back, and pintail ducks and whistling swans have suffered most, but a number of other species will probably be included in the list when the matter is more fully investigated.

Many opportunities have come to the writer to handle and examine ducks and other birds suffering from lead poisoning during the past three years, and he has had occasion to carry on experiments to ascertain the cause and manner of the affection. The results are outlined in

NOTE.—This bulletin is a report of studies made of a serious malady among ducks and other waterfowl in the United States. It is for the information of sportsmen, naturalists, and others interested in game birds.

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the following pages. During the course of the work the Bureau of Chemistry has cooperated in making analyses to determine the presence of lead in portions of the viscera of affected birds.

HISTORY.

At various times during past years there has been discussion in sporting magazines regarding the presence of shot in the stomachs of wild ducks. More recently attention was called to lead poisoning in ducks by J. H. Bowles[1] in 1908. On the Nisqually Flats, a large marsh area in the Puget Sound district, Washington, a number of mallards had been found sick or dead. Examination of three of these revealed a quantity of shot still held in the gizzard. The Nisqually Flats have been famous ducking grounds since early settlement in the State, so that it may be supposed that shot are present in the mud in abundance.

Lead poisoning was reported in 1908, also, among canvas-back ducks on Lake Surprise, Tex., and an account of it was published by W. L. McAtee, of the Biological Survey.[2] Lead poisoning in this locality apparently had been known for several years. It was stated that canvas-backs resorted to Lake Surprise in November each year, and affected birds appeared in the rushes along shore about the first of January, while as the season advanced these sick birds died and disappeared. From all accounts, no other species of ducks were affected here.

Examination of several whistling swans from Back Bay, Va., sent to the Biological Survey during January, 1915, showed that these birds were suffering from lead poisoning, as from 22 to 45 shot pellets were found in the gizzard of each. On inquiry it was learned that sick swans were found in January every year, and that the trouble among them continued until March. The malady, known locally as the "keuk," was said to affect canvas-backs and other ducks and geese as well as swans.

During the summers of 1915 and 1916, while working in the marshes formed in the Bear River Delta at the northern end of Great Salt Lake, Utah, the writer handled many ducks suffering from lead poisoning. Here the species affected were mallards and pintails, the majority being males. Birds sick from poisoning were found from June to September, and the total number that died was considerable, though insignificant when compared with the numbers destroyed here by other diseases.

Reports of sick ducks in other localities in the United States seem to indicate lead poisoning as the causative agent, but material has not as yet been available to substantiate this. It is believed that the trouble is more or less prevalent throughout the country.

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[1] Auk, XXV, pp. 312–313, 1908. [2] *Idem*, p. 472, 1908.

SPECIES OF BIRDS AFFECTED.

The list of species of birds at present known to have been poisoned by eating shot is small, but it will undoubtedly be increased when the facts are better known. In the following brief list all but one species (the canvas-back) are included from personal observations of the writer:

Mallard (*Anas platyrhyncha*).
Pintail (*Dafila acuta tzitzihoa*).
Canvas-back (*Marila valisneria*).
Whistling swan (*Olor columbianus*).
Marbled godwit (*Limosa fedoa*).

Lead poisoning is a common affection in all these except the marbled godwit. Only one specimen of this bird that had died from eating shot has been examined. In this species and in other shore-birds lead poisoning is probably rare. Geese and several species of ducks in addition to those listed above are said to have been affected in various localities, in particular on Back Bay, Va., but these reports have not as yet been investigated.

As has been stated, the shot secured are taken while feeding. Pintails and mallards delight in working in shallow water, where they dig away the mud to a depth of 6 to 18 inches, in search of succulent roots and tubers. In this manner they work over extensive areas, forming "duck holes" from 1 to 15 feet or more in diameter. Swans feed in much the same manner, but, with their long necks, are enabled to work in deeper water. The canvas-back is a diving species that digs constantly in the bottom mud and frequently feeds at a considerable depth. With all these birds certain quantities of gravel or grit of some kind are necessary for the proper grinding, or trituration, of food in the gizzard to put it in proper form for the extraction of nutriment. In the mud of marshes and lowland lakes little gravel is present, and to secure this needed element the birds in feeding develop a tendency to swallow any small, hard object they encounter. In this way the shot that have accumulated about shooting points are swallowed one by one. The bird may be several days or even longer in securing a fatal dose or it may pick up a large number of pellets at one time. In either case the shot are held in the gizzard to be slowly ground away, only small particles of lead passing on into the intestine.

SYMPTOMS OF LEAD POISONING.

The symptoms of lead poisoning as observed in waterfowl are similar in many ways to those found in mammals. A prominent indication of this malady is a paralysis of important muscles, which increases steadily as the ailment progresses. This paralysis seems first to affect the nerves supplying the great pectoral muscles of the

breast, and in a very short time the birds are unable to fly. (Pl. I, figs. 1 and 2.) Following this the wings begin to droop from the sides. In many cases the extensor muscles supporting the wing tip, that portion of the fore limb homologous with the hand, are seriously affected, and the wing hangs from the carpal joint, a symptom strikingly like the "wrist drop" found in many cases of lead poisoning in man. The wings float loosely on the surface when the affected birds are in the water, and in severe cases the tips of the primaries may drag as the bird walks about on the ground. Other muscles are affected as well. When the bird is standing, the breast is depressed and the tail droops. (Pl. II, fig. 2.)

After a few days birds often experience difficulty in walking and may fall as they attempt to turn around. This paralysis of the legs grows until the body can no longer be supported, and in moving about the birds slide along on the breast. (Pl. I, figs. 1 and 2.) This loss of function in the muscles is not always symmetrical; in several cases muscles on the left side were more severely affected than on the right. This was especially noted in the leg muscles. In many of the living birds studied the poisoning due to ingested shot was acute, and death came in a few days. In others the condition became chronic, and the birds, much emaciated, lived from two to five weeks. Often an adult mallard would waste away until the large muscle masses of the breast were reduced to slender fasciæ that were barely sufficient to cover the sternum.

The feces of affected birds are thin and watery and stained green. This color is a well-marked symptom. When fecal matter comes largely from the rectum the green is very dark, but when mixed with renal matter in the cloaca it becomes paler. In this case the green color, though lighter, is remarkable for its brightness. The body temperature of affected birds is normal, unless the individual is anaemic, when it is subnormal.

In weak birds the eye was usually very bright and the muscle controlling the nictitating membrane not affected. During field work in Utah this point was used as a ready means of distinguishing these birds from individuals helpless from poisoning due to alkalies.[1]

The heart of a bird suffering from lead poisoning is affected, and the bird may die suddenly after fright or exertion. Captives under observation were liable to spasms after they had become much weakened, during which they fell on the breast with head and wings extended, and were agitated by slight but rapid tremors. In some cases this caused the lower mandible to rattle against the upper. These spasms were followed by periods of weakness, when for a time the birds lay motionless, but later were able again to walk about. The

[1] Cf. Wetmore, Alexander. The Duck Sickness in Utah: Bull. 672, U. S. Dept. Agr., pp. 1–25, 1918.

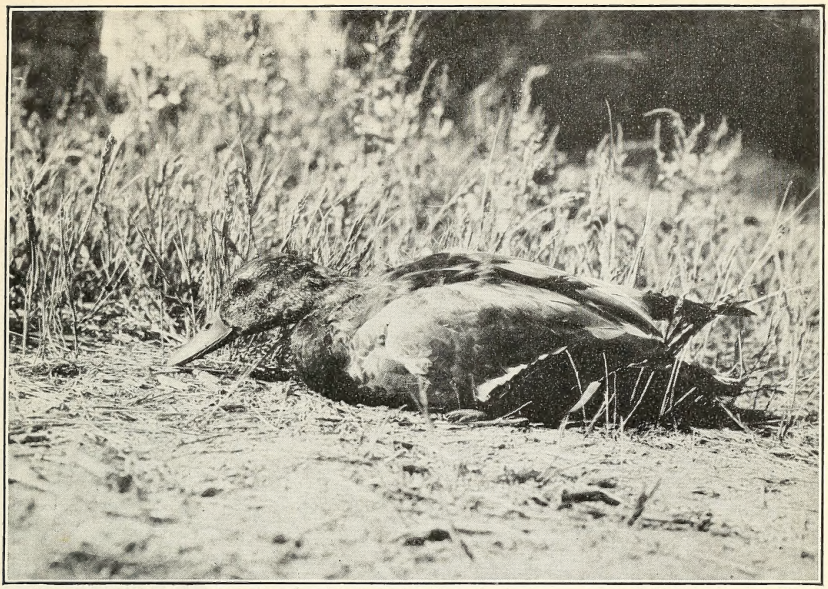

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FIG. 1.—MALLARD WITH LEAD POISONING.

The carpal joint of the wing is affected, simulating "wrist drop," and the bird has difficulty in walking.

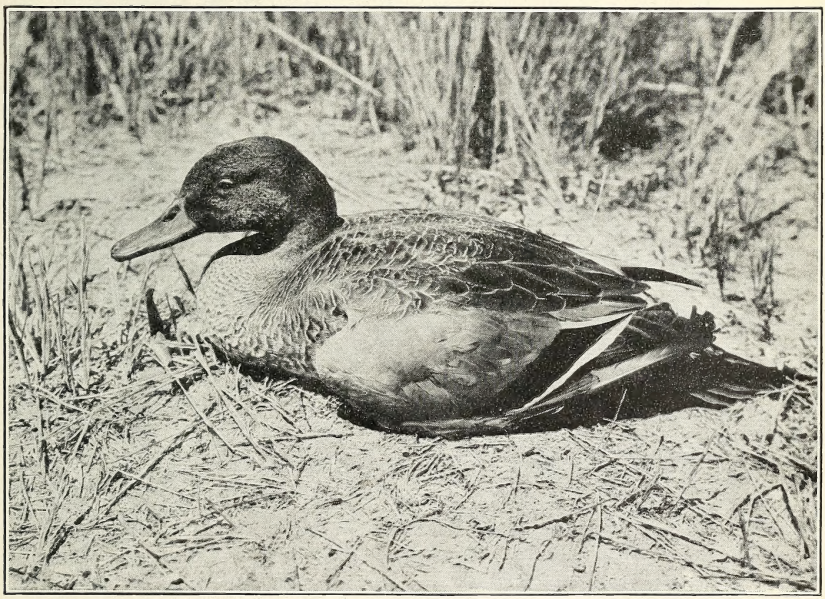

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FIG. 2.—PINTAIL WITH LEAD POISONING.

Paralysis of the legs renders the bird unable to stand.

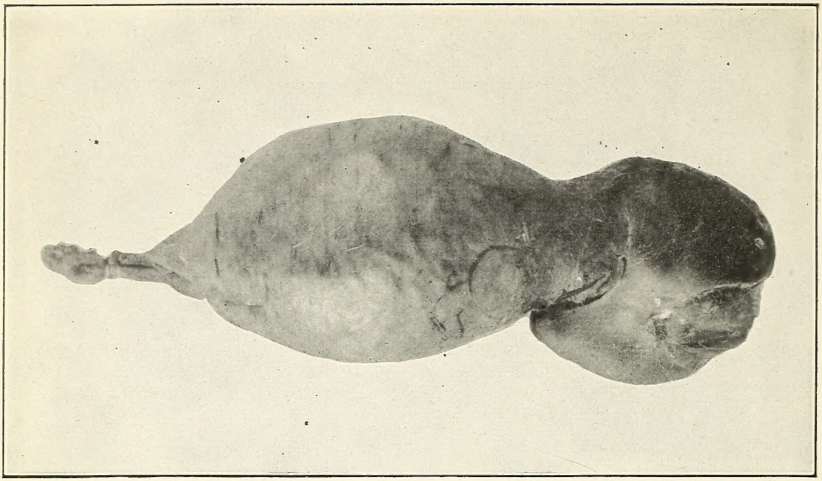

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FIG. 1.—STOMACH OF MALLARD THAT DIED FROM LEAD POISONING.

Abnormal distension of lower œsophagus and proventriculus with food produces a mass larger than the gizzard.

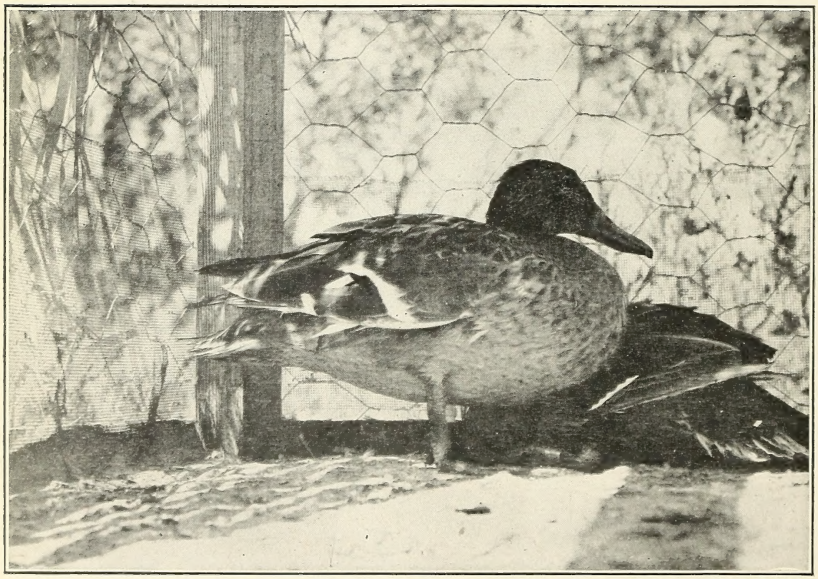

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FIG. 2.—MALLARDS WITH LEAD POISONING.

The breast is depressed and the tail droops when the bird is standing. In health the carriage is more erect.

heart seemed to be affected seriously, and the pulse in many cases was rapid and very strong. In one instance the heartbeat of a male mallard under observation in the laboratory was distinctly audible at a distance of 10 feet, but this was unusual. It was found that birds thus affected were liable to die after any fright or exertion that stimulated the heart action strongly. In one instance a mallard in the water dived to escape capture, and remained beneath the surface for 30 seconds. It came up, and attempted to dive again, but suddenly relaxed, and was dead. In other instances birds kept in experiment pens died while being handled. Death frequently came during the spasms described above.

Birds with lead poisoning always had good appetites, and ate eagerly. Often when they were so weak as to be unable to stand, the gullet and upper portion of the stomach were found to be crammed with food. These birds drank copiously and at short intervals. When disturbed they often regurgitated quantities of greenish fluid, a watery discharge that stained the mouth cavity and the tongue. No solids came with this. Birds of the groups affected are, in so far as the writer's experience is concerned, unable to return solids that have been swallowed.

POST-MORTEM APPEARANCE.

The flesh of birds dead from lead poisoning is in nearly all cases pale. This pallor was well marked in ducks that had been sick for some time, and occurred before a wasting of the muscles began. In chronic cases in which emaciation was extreme there was a marked pallidness of the larger muscle masses, and even of the viscera. The blood was slow to coagulate, and frequently remained fluid for 10 or 12 hours after death. Studies made of blood taken from living birds indicated a decrease in the number of red corpuscles, but as the apparatus used in making blood counts was imperfect, results from these examinations were far from satisfactory. At that time perfect counting chambers for the usual grades of hæmacytometers were not available on the market, so that conclusive studies of the effect of lead poisoning on the blood are yet to be made.

Examination of blood smears has failed as yet to show the presence of granules that have been noted in the case of lead poisoning in mammals. The heart generally was in systole. In case the bird examined had become weakened while in the water, so that actual death came through drowning, the ventricles were in diastole as is usual in birds that have drowned, but this was an abnormal condition. In chronic cases of a week or more in duration the pericardium was usually distended with a watery lymph, slightly tinged with brownish orange.

During prolonged cases of lead poisoning, the alimentary tract exhibited several changes that were characteristic of the trouble. In normal birds the ventriculus, or gizzard, and the crop may be crammed with food, but the proventriculus, or glandular portion of the stomach, is empty. In cases of lead poisoning from eating shot the appetite for food is greatly increased, while the gizzard seems slow in action, and observations indicate that the great muscles in its walls are more or less paralyzed. In these birds the proventriculus and the lower portion of the oesophagus are greatly distended with food, so that they form a mass larger than the gizzard itself and have their walls stretched to the utmost. (Pl. II, fig. 1.)

The pads lining the inside of the gizzard often appear more or less corroded and slough easily, while gravel may work up into the lower portion of the proventriculus, a condition that is unknown in the healthy animal. The contents of the gizzard were usually stained green. Occasionally this color extended through the food contained in the lower part of the proventriculus.

Generally the shot were found on washing out the matter contained in the gizzard, though a few were located in the lower end of the proventriculus. The usual number of shot in one stomach was 15 to 40. The largest number of pellets taken from one bird was 76, found in the gizzard of a mallard secured near the mouth of the Bear River, Utah. In September, 1916, during routine laboratory work, 28 mallards and 10 pintails that had died from lead poisoning were examined. From the stomachs of these 38 birds 939 shot were recovered, an average of a fraction less than 25 each. Where shot have been in the gizzard for a considerable time they are much worn, and in many cases are ground down to flattened disks by the action of the stomach muscles and the trituration with gravel.

The intestine may be irritated, or may be nearly free from distended capillaries. Observations on this point are uncertain, as the birds examined were from regions where the waters frequented contain irritant salts, usually in quantities sufficient to bring about a certain amount of congestion in the capillaries of the intestinal walls of the waterfowl. Where many shot are in the stomach the walls of the small intestine may be discolored, and in nearly every case there is a deposit of lead on the inner walls of the cæca. This deposit is most pronounced in the distal third of these blind guts, but may extend for their entire length. The cæcum appears lead colored from without, but when slit and examined its inner walls are found to be blackish. The gall bladder is always full and may be much distended. In one individual examined the gall bladder measured 30 mm. long by 12 mm. in diameter. The bile is very dark green, and after death this color may spread slowly until it has stained the

entire liver. This was noticed in particular in examining several whistling swans received at the Washington laboratory from Back Bay, Va.

RESULTS OF EXPERIMENTAL WORK.

During the field seasons of 1915 and 1916 a series of experiments dealing with lead poisoning in ducks was made at a field laboratory near the mouth of Bear River, Utah. Though shot had been found in many instances in the stomachs of birds, their presence had not been determined absolutely as the causative factors of the disease apparent in such individuals. The stomachs of a large number of ducks have been examined in the laboratories of the Biological Survey to determine the food habits of the species. These stomachs were from birds apparently healthy when killed. It is not unusual to find from one to half a dozen or more shot pellets in such stomachs, and in birds from certain localities pellets were almost always found. These facts cast some doubt on the supposition that ducks were affected unfavorably by eating shot, and it was necessary to test the matter by actual experiment.

For this purpose small pens 3 feet wide, 3 feet high, and 5 or 6 feet long were used. Each pen was placed on a platform a foot above the ground with a hole cut in one end to hold a water pan, and the boards were covered with earth. Ducks were taken from large stock pens and placed in these smaller pens as needed, while control birds were confined under similar conditions in separate pens. They were fed morning and evening on mixed grain containing wheat and barley in equal quantity.

Wild mallards, captured when young and reared to maturity, were used in the main experiments, so that there was no possibility of their having obtained shot before they were placed under close observation. Shot and lead were given to these birds through a small glass funnel. The lower end of the funnel was placed well down the duck's throat and after the shot were given a small quantity of water was poured down to insure that the pellets or particles should not lodge in the oesophagus. After treatment birds were watched closely for several minutes to make certain that none of the lead was cast out through the mouth. It was found that six pellets of No. 6 shot constituted an amount of lead that was always fatal. Two or three shot were sufficient to cause death in several instances, and as the number was increased the resistance of individual birds decreased. In one experiment two mallards were each given one No. 6 shot. One died 9 days later, while the other was able to throw off the effects of the lead and recover. Pintails and redheads were similarly affected. One male pintail was given four pellets of No. 6 and another six.

Both died, the former in 11, and the latter in 13 days. One redhead was killed by taking six No. 6 shot. Another was given four pellets of shot and was sick for some time, but finally recovered. Experiments were not tried with other species.

The symptoms in these birds were invariably the same, and it was proved beyond question that lead poisoning from ingested shot is a dangerous and usually fatal malady. In from 10 to 24 hours the feces of birds to which shot had been given were stained with green and were loose and watery in consistence. This green tinge increased until the fecal matter was very dark. Birds thus affected drank constantly, and frequently when disturbed regurgitated small quantities of more or less greenish water. As the malady progressed the affected ducks spent more and more time in the water pans and drank constantly. The excrement in 12 hours often was sufficient in quantity to color strongly 10 quarts of water.

Other symptoms and post-mortem appearances were similar to those described in previous paragraphs. Birds were affected more rapidly by soft shot than by chilled or hardened shot, but in either case the result was the same. Birds that had the stomachs well filled with gravel or that had access to an abundance of gravel were weakened more quickly than those that had been confined for some time where they could not secure grit. Apparently the rapidity with which they became affected was dependent upon the speed with which trituration in the ventriculus ground away particles of lead and passed them into the intestine. It has been mentioned that in post-mortem examinations the blackened lining of the cæca was found to be a prominent symptom of lead poisoning. It was supposed that this blackening was due to the presence of lead sulphide formed by the action of hydrogen sulphide upon lead particles present in the intestine. Analyses made in the Bureau of Chemistry proved that this was not true in the majority of cases, as only a trace of lead sulphide was detected in one sample in six submitted for examination. The quantity of lead present in the cæca seemed somewhat correlated with the number of shot in the stomach. Table I gives the results of the six analyses.

TABLE I.—*Relation between number of shot in stomachs of waterfowl and quantity of lead in cæca.*

Species.	Number of shot in stomach.	Quantity of lead detected in cæca.	Species.	Number of shot in stomach.	Quantity of lead detected in cæca.
		Mgm.			*Mgm.*
Mallard	4	0.20	Mallard	34	0.55
Do	11	.20	Do	48	.55
Do	17	.27	Pintail	5	.15

After experiments had fully established that shot were capable of poisoning waterfowl, the question as to whether the diseased condition was caused by lead or by some other substance present in the shot remained to be settled. Arsenic is a common impurity in commercial lead, and in the manufacture of shot a certain quantity is usually added. This is said to be necessary to make the lead pellets spherical when dropped and also to harden them. As arsenic and lead in combination are used to form poisonous compounds for killing insects and for other purposes, it might be supposed that these compounds were active in cases of poisoning from shot eaten and held in gizzards of waterfowl. In several experiments, therefore, ducks were given quantities of granulated lead equal in weight to the number of shot that in other cases were found to be fatal. The granulated lead had the same effect as the shot in each instance, proving that lead was the active agent in the poisoning. Birds seemed to die more quickly from the effects of the granulated lead, as the particles were numerous and so small that they were readily ground up and passed into the intestine to be absorbed.

PREVALENCE OF SHOT IN MARSH AREAS.

Many marshes, lakes, and bays in the United States are noted as resorts for waterfowl, and are visited each year during the hunting season by sportsmen in pursuit of game. Owing to the configuration of the land and water areas and the habits of the birds pursued, there are points or islands in these places that afford good shooting each season, and in many cases blinds to conceal the hunters are located on or near the same spot year after year. In time a great mass of waste shot pellets will gather about these points. The action of the water, especially where it is more or less saline or alkaline, tends to corrode these shot somewhat, but this process is in most cases very slow, so slow, indeed, as to be hardly appreciable. As corrosion takes place, there forms over the surface of the shot a scale, which, as it thickens, protects the lead more and more from further chemical action. There can be no question that shot pellets may last for many years.

To ascertain the presence of quantities of expended shot in these marsh areas the writer with an assistant examined the mud near two localities in the shooting grounds at the mouth of Bear River, Utah, from each of which several thousand shells are fired each season.

For the first experiment a small island known as Bayless Island was selected, on which a blind had been placed each season for about 20 years. In searching for shot an ordinary sieve with a mesh small enough to hold No. 7 shot was used. Mud was shoveled into this and washed through the wire. The mud here was soft for a depth of 5 inches; below this was a hardened clay. Sifting was begun at

a point 30 yards from the blind and was continued at 20-yard intervals in a straight line out from the shore to a distance of 210 yards from the island. About 10 quarts of silt were examined from each spot. Shot first appeared at a point 70 yards out and were found at each station to the place where sifting was stopped. The pellets were most abundant at a distance of 130 yards, where from 1 to 12 were recovered in each sieve filled with mud.

On another day sifting was tried near Bigelow's Point, a locality about 2 miles west of Bayless Island. Here a blind had been located on a small island for at least 20 years, and another island 200 yards south had been used as a shooting stand for the same period. In addition to these, many temporary boat blinds have been built in the open bay offshore. Sifting was carried on here in the same manner as at Bayless Island in a line that included ground within shotgun range of both blinds. The first mud was examined at a distance of 30 yards from Bigelow's Point, and sifting was continued at 20-yard intervals for a distance of 230 yards. Shot were secured from each sifting for the entire distance and from 1 to 13 pellets were found at each station. At stations more than 150 yards from the blind, from 20 to 22 shot were recovered from each of three lots of mud taken at one point. The surface mud here was very soft for a depth of 12 inches, below which was a hardened clay. The great mass of shot had penetrated through the soft surface layer of mud and lay at a depth of 10 to 12 inches.

On this entire marsh there can be no question that 75,000 or more shotgun shells are used each season. As each shell contains approximately an ounce of shot, the great accumulation of the lead pellets about blinds that are favorably located may be imagined readily. The majority of the shot that were recovered by sifting were soft; only a small part were chilled. This may serve to indicate that a large part are comparatively old, as at present chilled-shot loads are used. The soft shot in question were all more or less battered and scarred from muzzle compression as they left the gun or from other causes. All were dulled in color, indicating slight surface oxidation, but none showed any distinct corrosion, though the clay below the softer mud was often strongly saline.

These facts point to a steadily increasing body of shot pellets in the mud of these marshes, as there are undoubtedly in other marshes on which shooting is extensive.

CONCLUSIONS.

From his own observations and from others the writer has learned that lead poisoning due to eating shot is of common occurrence among waterfowl, and from the manner in which the shot are se-

cured it seems reasonable to suppose that this disease will continue and will increase as time goes on. It seems probable that cases of lead poisoning may be found among upland game birds, as pheasants thus affected have been known for many years on extensive shooting preserves in England.[1] Diseased birds were usually found on such estates a short time after the close of the hunting season, and from 1 to 3 shot pellets have been taken from the gizzards of sick pheasants examined.

A point that may develop greater importance than the direct killing of individual birds by lead is the effect that lead may have upon the constitution and bodily functions of birds that do not actually succumb to its poisonous properties. It is well known that lead acts as an abortifacient in females of mammals. No information on its action in female birds during the breeding season is at hand. In experiments performed by L. J. Cole, at the Wisconsin Experiment Station, it was found that lead administered to male domestic fowls had a powerful effect upon their virility.[2] This was indicated by infertility of many eggs and a high percentage of deaths in embryos and in young chicks soon after hatching. Lead poisoning in the male in these cases distinctly affected the vitality of the offspring. If it should be found that lead poisoning affects males of wild ducks and other waterfowl in a similar manner, this may prove to be a factor of importance in the diminishing numbers of these birds. In such cases the poison will be of detriment even in those birds that seem tolerant of its effects.

At the present time all that can be done in regard to lead poisoning is to call attention to its prevalence and to describe its cause and symptoms, that they may be understood by persons finding birds thus affected. No suggestions of a practical nature can now be made to alleviate this danger to our waterfowl. The writer has been able to effect a cure in a few individuals by treating them with magnesic sulphate. Wild birds that were brought into the laboratory with lead poisoning were confined in small pens, where they were supplied with a solution containing 60 grams of magnesic sulphate in 10 quarts of water. This was renewed daily. As magnesic sulphate forms an insoluble compound with lead, this solution tended to neutralize the lead particles as they were given off into the intestine. The color of the feces in birds treated changed at once from bright green to olive brown. This treatment was tried on a small number of ducks, and about 50 per cent recovered. The method is of interest as an experiment but has little or no practical value, as the time required for treatment was prolonged and the result was somewhat uncertain.

[1] Cf. The Field (London), vol. 47, pp. 189, 267, 1876; and vol. 59, p. 232, 1882.
[2] Wisconsin Exp. Sta., Bull. 250, pp. 44–45, 1915.

Various suggestions have been made to combat this trouble but none is at all efficacious. Some persons, supposing that the birds swallowed the shot because of a lack of gravel on their feeding ground, have proposed supplying grit and sand in the marshes in the belief that the birds would use this and not eat the shot. As has been said before, ducks in feeding seem to swallow any small, hard objects that they encounter, so that such supplies of gravel would be of no aid in preventing lead poisoning. It has also been suggested that the mud flats be harrowed in some way to cause the shot to sink beyond reach. This, however, would be of no avail, as ducks in feeding often dig in soft mud to a depth of 12 to 16 inches.

Statistics on the number and species of birds affected by lead poisoning from eating pellets of shot will be of interest, and it is hoped that sportsmen and others will report cases that come to their attention. There can be no doubt that the trouble is found in many extensive marsh areas throughout the United States in addition to those mentioned in this report.

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